Volume 12 DECEMBER 1928 Number 12

BULLETIN

of the

American Association of Petroleum Geologists

CONTENTS

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of the

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

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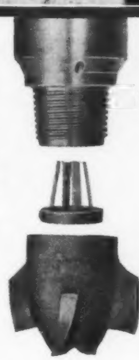

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AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

Vol. 12 **DECEMBER 1928** **No. 12**

CONTENTS

Articles Scheduled for Publication in the January *Bulletin*

Studies in Differential Compaction

By C. M. NEVIN and R. E. SHERRILL

The Nature of Uplifts in North-Central Oklahoma and Their Local Expression

By C. M. NEVIN and R. E. SHERRILL

Origin of the En Échelon Faults in North-Central Oklahoma

By R. E. SHERRILL

A New Graphical Method for Torsion Balance-Topographic Corrections and Interpretations

By C. A. HEILAND

Is Geologic Distillation of Oil Possible?

By WILLIAM L. RUSSELL

Volume 12 Number 12

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DECEMBER 1928

BIG SAND DRAW FIELD, FREMONT COUNTY, WYOMING[1]

COLIN C. RAE
Denver, Colorado[2]

ABSTRACT

The Big Sand Draw field, in Fremont County, Wyoming, has produced approximately 20,000,000,000 cubic feet of gas from the upper Frontier formation (Cretaceous), with showings of oil in an edge well. Rock pressure is still more than 1,000 pounds per square inch.

Although the field is not comparable in area with the Salt Creek field, it is of exceptional geological interest, since it has a proved closure of approximately 1,300 feet, and has several untested lower sand horizons, which are productive in other Rocky Mountain oil fields.

INTRODUCTION

The Big Sand Draw gas field is one of the major gas fields of Wyoming, supplying gas to the towns of Riverton, Hudson, and Lander, besides supplementing the Casper supply. There are still possibilities for oil on the flanks of the structure in the known gas sands, or in the several untested, possibly productive horizons below the gas sands. The field is about 20 miles southeast of Riverton, Fremont County, Wyoming, the productive area being in T. 32 N., R. 95 W., of the sixth principal meridian.

HISTORY OF DEVELOPMENT

Although the Big Sand Draw anticline was known for many years, no test wells were drilled because of uncertainty about the closure, inasmuch as the south end of the structure was covered by heavy wash

[1]Read before the Association at the Tulsa meeting, March 26, 1927. Revised manuscript received by the editor, October 18, 1928.

[2]Present address, U. S. Geological Survey, Okmulgee, Oklahoma.

and flat-lying Tertiary rocks. The United States Geological Survey studied the area in 1915-16, and made a withdrawal of promising possible oil structures, but did not withdraw this anticline. The field was located under the oil placer laws by Riverton and Denver parties early in 1917. The discovery well was completed by the Producers and Refiners Corporation on the SW.¼ of Sec. 10, T. 32 N., R. 95 W., in October, 1917, with a flow of approximately 10,000,000 cubic feet of gas daily from the upper Frontier sand.

Several additional wells have been drilled, resulting in further extension of the proved area. Wells drilled down the flanks of the dome found gas equal in volume and pressure to that on top of the structure. Due to the narrow, sharp fold, the exact height of the structure is not known, but it seems probable that a well on the axis in the SE.¼ of Sec. 15, T. 32 N., R. 95 W., may be still shallower than the present well in the SW.¼ of Section 14. Considering only the high point established by that well, the gas zone in the upper Frontier sand has extended more than 1,050 feet down the dome. The Producers and Refiners Corporation's well No. 2 in Section 9 reached the heavy-pressure gas sand about 1,371 feet down the structure, and is reported to have found light green oil of 40° Bé gravity in the first 2 feet of sand, but water in the remainder of the sand. It seems probable that this well is close to the closing contour.

For several years, efforts to penetrate the gas sands were not successful, due to lack of proper facilities for handling the heavy pressure. The wells on the flanks were reduced to such small holes with the depth, that deeper tests were impossible. The wells on the top of the structure found a gas pressure greater than the hydraulic head of water. The wells blew out of control, resulting in a great waste of a natural resource, besides danger to life and property from fire. All these wells were "junked" by fishing jobs or collapsed casing before a few hundred feet of Frontier could be drilled. After about four years, the use of mud fluid was attempted. In order to obtain the required pressure, such heavy mud was used that the tools stuck and did not make much progress. When the fluid was thinned a little, the wells would start to throw fluid from the hole. As a final result, the wells using mud fluid did not succeed in going much deeper into the Frontier than the open-hole tests had gone. The use of rotaries, heavy barite, or ferric oxide mud fluid may be necessary to protect the gas zone against loss while drilling to lower formations.

The Texas Production Company has drilled its first well, using barite mud. The gas was controlled, but drilling was slow under the barite mud, probably because the shale did not mix properly under the head of mud, as sandy streaks seemed to drill faster. The loss of a string of casing by "freezing" with only about 400 feet of friction was caused by the barite mud, according to the drillers. This well has found a very heavy flow of gas in a sand in the second Frontier zone with about 1,200 pounds pressure, but mechanical difficulties stopped the progress of the well. The Producers and Refiners in the SW.¼ of Section 14 also have reached the second Frontier zone, and may be able to go deeper, to test the two lower Frontier sands and even the Dakota series. The pioneer work in any new field is surrounded with difficulties, but experience causes drilling practices to be altered to meet the situation.

The amount of gas produced by different wells is always proportional to the distance drilled into the Frontier. The larger wells, making from 30,000,000 to 40,000,000 cubic feet, are about 200 feet in the Frontier, which is approximately 650 feet thick. Each new sand carries more gas under high pressure (more than 1,000 pounds) and even sandy streaks in the shale carry gas flows. Considering all the gas wasted and sold, the pressure in the upper sands has declined very little, still being more than 1,000 pounds per square inch, which shows a reservoir greater than is shown by the contours of the structural map, which may be due to the sands being thicker than indicated in the geologic section. Tests made on drillers' "sandy shale" indicate mostly sand. The total developed gas is approximately 250,000,000 cubic feet daily.

The early records of gas lost into the air are too incomplete for accurate estimate, and the pressures increase slightly with depth in the Frontier. However, the pressure-production-decline curve from December, 1925, to December, 1927, indicates a decline in pressure in the first zone from 1,100 pounds to 1,043 pounds in a delivery of 7,500,000,000 cubic feet. This indicates an approximate content of 125,000,000,000 cubic feet down to 100 pounds reservoir pressure. The second zone may increase this estimate to 200,000,000,000 cubic feet ultimate gas production for the first two zones from January, 1928.

STRATIGRAPHY

The surface rocks in the proved area of the field are Cretaceous, obscured by recent wash and flat-lying rocks of Tertiary age. The sequence and thickness of formations in this area are shown in Table I.

The Tertiary formation gives little information about folding, being chiefly unconformable, flat-lying beds. A few gentle dips of a few degrees indicate that some movement may have taken place after the Tertiary was deposited, but it does not coincide with the present axis.

Some brown sandstone beds in the Pierre about 3,000 feet above the Frontier crop out in the northeast part of the field.

The important formations are the possible oil and gas horizons in the Frontier and Dakota groups.

Frontier formation.—As elsewhere in Wyoming, the Frontier sands differ in thickness and shale content, since the sands in general are lenticular. About half of the formation is sand in this area. It is gen-

TABLE I

GEOLOGIC SECTION

System	*Formation*	*Thickness in Feet*	*Character of Rocks*
Recent	Unconformity		Soil, gravel, wash, and boulders
Tertiary (undifferentiated)	Wind River, etc.	0–4,000	Variegated shale, brown sandstone, arkose, loosely cemented, high-colored sandstone
Cretaceous	Lewis shale	0–800	Sandy blue shale
	Mesa Verde	1,000	White or light-colored massive sandstone with coal and some carbonaceous shale
	Pierre	2,700	Blue and gray sandy shale with thin brown sandstone
	Niobrara	1,450	Light limy blue shale
	Carlile	250	Light-colored, brown, and sandy shale
	Frontier	650	Gray sand and shale with some bentonite Carbonaceous material in center of formation About five main sands
	Mowry	300	Fissile dark shale and bentonite
	Thermopolis	50–200	Dark shale
	Cloverly or Muddy or Dakota	40	Brown massive sandstone
		130	Shale
	Lakota	70	Sandstone
		80	Shale
	Conglomerate	15	Conglomerate

erally found in Wyoming that where the lower Frontier sands are well developed and continuous, the lower sands are more productive than the upper sands. At Grass Creek the upper 40 per cent of the Frontier carries water or gas and the lower part is oil-bearing. At Salt Creek, the productive area in the first Frontier sand was originally about 4,400 acres compared with 21,000 acres in the middle Frontier. At Oil Mountain, about 8 miles east of the Big Sand Draw field, the Frontier outcrop shows saturation in the lower sands.

The first sand zone at Oil Mountain is not uniform in content. It is about 165 feet thick and consists of 125 feet of sand, shale, and "shells," underlain by 40 feet of massive gray sandstone. The change from the dark brown sandy shale of the Carlile to the gray sandstones and shales of the Frontier is usually noted on the well logs, especially since it is marked by a hard quartzite bed or "shell," a few feet thick. Below this shell is usually found a few million feet of gas, which increases gradually to about 10,000,000 cubic feet in the 125 feet until the drill reaches the 40-foot massive sandstone, where it increases to about 40,000,000 cubic feet. This sand is the main producing horizon of the field, and no wells except the Texas well in the SE.¼ of Section 15 and the Producers and Refiners well in the SW.¼ of Section 14 seem to have reached any sand below this zone.

The sequence of beds below the first sand zone is as follows: 100 feet of shale; a second Frontier sand about 30 feet thick; 40 feet of sandy shale; a third 50-foot sand; 80 feet of shale; 120 feet of sandstone; 30 feet of shale; and 45 feet of sandstone. The two lower sands show saturation.

Dakota group.—The oil horizons of the Dakota group include 40 feet of Muddy, or Dakota, brown sandstone, 70 feet of Lakota sandstone, and 10 feet of sandstone in the conglomerate. The "sands" are separated by shale as shown in Table I and Figure 1.

Other formations.—The recent discoveries of commercial oil production in the Sundance formation at Salt Creek and Lost Soldier have indicated that this structure is in a favorable location for prospecting the Sundance formation.

The commercially profitable black oil production of Wyoming is in the Chugwater, Embar, and Tensleep formations. It seems to be limited by conditions of sedimentation to the areas adjacent to Owl Creek and Wind River Mountains, and the Big Sand Draw dome may be considered encouraging for prospects of black oil, when the upper beds have been exhausted.

STRUCTURE AND PROSPECTIVE DEVELOPMENT

The Big Sand Draw dome is a narrow sharp fold with a probable closure of more than 1,300 feet and an area of more than 1,800 acres.

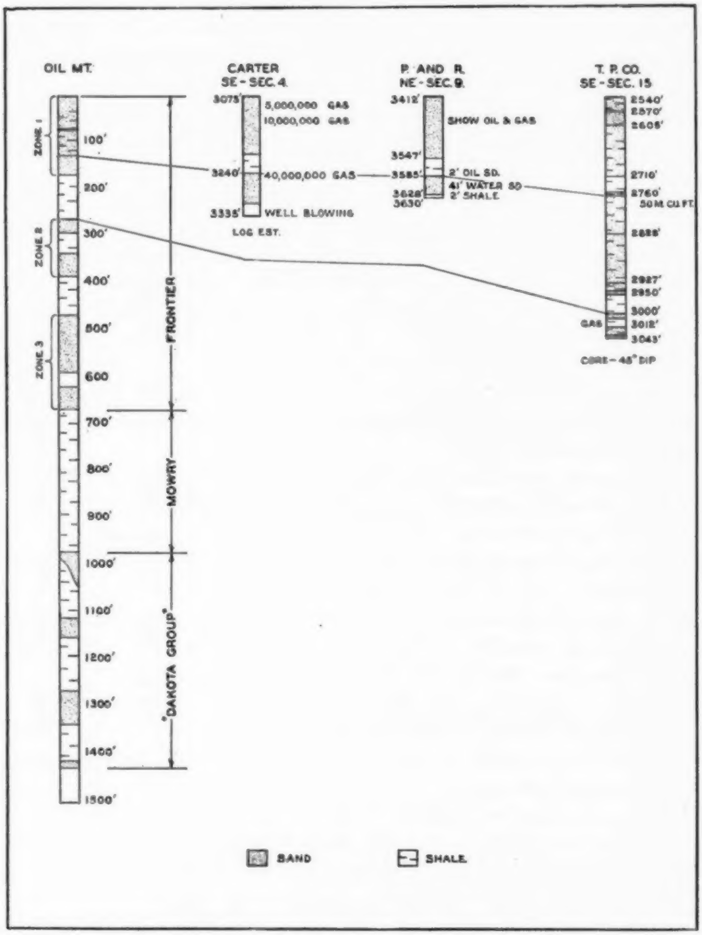

FIG. 1.—Geologic section at Oil Mountain, T. 33 N., R. 94 W., compared with logs of wells in Big Sand Draw field, Fremont County, Wyoming. Depths shown in feet; gas production in cubic feet.

Since the structure is covered with Tertiary and gravel deposits along the west and the south ends, the sinuous axis and sharp fold make subsurface work more difficult. The general dips and subsurface mapping indicate that the east and west dips of the dome are approximately the same as farther north along the anticline in the next township. The dips range from 30° to 45° W. and from 20° to 40° E. Minor changes in strike and dip along outcrops on the east side of the field may indicate a sinuous axis, or there may be faulting, especially near the north line and center of Section 14. Most sharp folds of similar age in Wyoming are faulted, and although outcrops are not sufficient to map faults in the soft shales, there is every reason to expect evidence of faulting if the field is closely drilled. Faulting, however, does not adversely affect Rocky Mountain structures, since all producing fields are more or less faulted. Constant subsurface mapping and studies during drilling development of the field will solve the problems as they occur. Naturally the great range in dips from 9° to 45° causes trouble in correlating logs, and even where the surface dip is known, the subsurface studies indicate changes probably caused by a shifting axis.

The people who located the field prior to drilling were encouraged by the slight south Tertiary dips in the south end of the field, and more or less irregular southeast dips near the south line of Section 14. Recent pits have verified the southeast dips. The structure may extend farther south than indicated on the structural map (Fig. 2), and the axis may change again south of the well in Section 23. The history of the field has been a constant extension toward the south, but with southeast dips now defined, the extension will not be so important.

As the closing contour cannot be defined accurately by adjacent synclines, the closure has been considered to be the limit of the gas production. It may be possible to have the production in the lower Frontier cover a larger area, as at Salt Creek.

The subsurface contours of the lower sands and Dakota group would probably be a little east of similar contours on the upper Frontier, due to the nature of folding.

Some structures are dry or produce only gas in formations and areas known to be favorable to oil production. There are different opinions as to the causes of such conditions. The regional metamorphism indicated by adjacent coal deposits is favorable to the formation of oil. The sharp fold and dips seem to indicate crumpling or faulting, which is common to most Wyoming structures, a condition considered by some a requisite for the accumulation of oil. The large closure with sharp

folding does not make logical the flushing of oil, leaving the structure full of gas, but some may suggest that theory, as the outcrop of Frontier on Oil Mountain 8 miles east would give an approximate head of 2,500 feet on the crest at Sand Draw, although it seems as if the natural flow of underground waters would be chiefly northward. The effect of len-

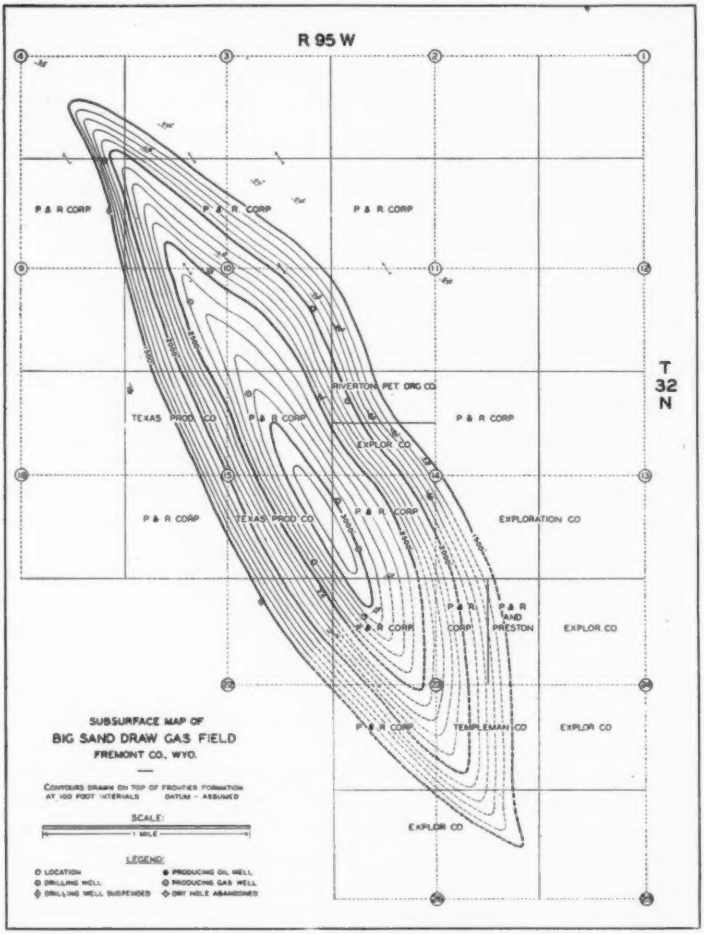

FIG. 2.—Subsurface map of Big Sand Draw gas field, Fremont County, Wyoming.

ticular sands on the flushing theory must also be considered. If the structure accumulated gas and oil, and the gas gradually forced the oil out of the sands, it would be exceptional to have that happen in so many different sands. Many of the gas fields in Wyoming, such as Mahoney dome, Wertz, Poison Spider, Oregon Basin, and Byron, did not produce commercially profitable gas from the Frontier formation, but developed the main flows in lower formations. Even Buffalo Basin, with water in the upper section of the Frontier, gas in the lower part, and the Dakota series untested, is not a direct comparison, especially when Grass Creek, a fold adjacent to Buffalo Basin, produces only water and gas in the upper part and oil in the lower part of the Frontier. Thus it is difficult to draw definite conclusions as to oil content prior to testing with the drill. The oil saturation at Oil Mountain gives all the encouragement and justification necessary for tests of all sands at different points on the structure.

The showing of crude oil with water in the gas sand in an edge well in Section 9 was encouraging to the hope that there will be a commercial oil zone bordering the gas in some of the Frontier sands, as oil has been found in the Rocky Mountain area on the flanks of gas sands in several folds, for example at Greybull, Teapot, and Wellington.

Some of the gas wells make a head of a few barrels of lemon-colored oil. This oil seems to make a maximum flow after the well is shut in for about three days, not increasing thereafter. The analysis of the oil (Table II) shows it to be a naphtha, not a condensate. It may be possible that capillarity in the fine-grained sand causes the accumulation of a certain proportion of the fluid in pores of the sand surrounding the well, and the first flow of gas expels it. It resembles the yellow naphtha of the Sarakany gas zone in the Baku fields, where the normal crude oil was found deeper. A study of the gas pressure, closure, depth, and detailed analysis of fluid with gas in similar sands of the Rocky Mountain area may be valuable.

It is interesting to note that normal green crude oil has been found in an edge well of the upper gas sand which produces the lemon-colored naphtha.

The probability of oil or a greater productive area in the lower Frontier sands has been emphasized previously in this paper.

The Dakota group oil horizons have been productive throughout a widespread area in the Rocky Mountain district. Cat Creek, Montana; Salt Creek, Lost Soldier, Rock River, and other fields in Wyoming; Craig and Wellington in Colorado, show the general favorable oil or gas

TABLE II

ANALYSIS OF LEMON-COLORED OIL BY MID-WEST REFINING COMPANY
Gravity 44.6° Bé. Initial Boiling Point 230° F.

Date, 8/2/18 Per Cent Off	*Temperature in °F.*	*Gravity in °Bé.*
10	276	51.0
20	285	49.0
30	300	47.6
40	316	46.7
50	332	45.2
60	345	44.1
70	354	42.8
80	376	41.3
90	402	40.7
95	425	38.2
99.1	475	36.5

Dry point, 470° F.
99.1 per cent distillate—44.7° Bé. gravity.
Flash of distillate, below 77° F.

prospects of these sands. At the nearest producing oil field, Lost Soldier, located about 40 miles distant, Krampert of the Prairie Oil Company states that when the Dakota sand oil wells are shut in, the Frontier sand wells increase in volume and pressure, showing a probable source of oil.

As the Sundance formation has been found very productive at Salt Creek and Lost Soldier, it is a probable reserve of oil or gas at Big Sand Draw.

The black oil formations should be productive of oil in this field when the upper sands are exhausted and the price of oil justifies the very deep drilling.

SUMMARY

The Big Sand Draw field is a narrow fold with large closure and a fairly large proved gas area. The oil saturation of the lower Frontier formation on an adjacent outcrop, and prospects of oil or gas in the Dakota group, Sundance, and black-oil formations offer reasonable encouragement that oil or gas may be found in the lower untested sands. Geologic conditions also justify the prospecting of the gas sands down the flanks of the structure probably between the contour of the lowest gas well and the contour of the "edge" well in Section 9. The lower Frontier sands found in the Texas well may have oil higher on the structure than in the upper gas zone.

METHOD OF EXAMINING CALCAREOUS WELL CUTTINGS[1]

C. B. CLAYPOOL[2] and W. V. HOWARD[3]
Urbana, Illinois

ABSTRACT

The necessity of making quantitative mineralogical analyses of calcareous cuttings has led to the development of a rapid method for the determination of the quantities of calcite and dolomite in material of this kind. This method, which is essentially centrifuging in heavy solutions, is described in this article.

In the study of limestone samples, whether from cores or well cuttings, accurate lithologic correlations are necessary.

Correlation by the general appearance of the samples or cuttings may be satisfactory, but if two limestones closely resembling one another are in contact, it may not be possible to observe the contact. Correlation by means of chemical analyses is far too slow and is unnecessarily accurate, inasmuch as many of the samples on which the work is done do not represent averages. Moreover, since this method does not show in what form the elements occur, analyses may receive several different interpretations. Correlation by means of heavy minerals is inadequate, since in many limestones they are lacking, and in others they are formed as a result of secondary processes irrespective of bedding planes.

A quantitative mineralogical determination by means of the microscope is unsatisfactory, because it is particularly difficult to determine whether or not the carbonates are calcite, dolomite, magnesite, or a mixture of all three, and it may be on this point that the whole correlation depends.

A method suggested by Earl A. Trager[4] consists of grinding the sample to 80 mesh, measuring, dissolving the carbonates in hydrochloric

[1]This paper contains preliminary results obtained in an investigation of limestones and dolomites as reservoir rocks, listed as Project No. 23 of American Petroleum Institute Research. Financial assistance in this work was received from a research fund donated by the Universal Oil Products Company to the American Petroleum Institute. This fund is being administered by the Institute with the coöperation of the Central Petroleum Committee of the National Research Council. Manuscript received by the editor, October 8, 1928.

[2]American Petroleum Institute Research Assistant. Introduced by K. C. Heald.

[3]American Petroleum Institute Research Fellow. Introduced by K. C. Heald.

[4]"A Laboratory Method for the Examination of Well Cuttings," *Econ. Geol.*, Vol. 15 (1920), pp. 170-76.

acid, and centrifuging the residue in water for the separation of sand and shale. This method does not separate the calcite and dolomite, and if anhydrite is present it will be partly dissolved and will, therefore, be considered in part as carbonate.

The most satisfactory method seems to be to separate the minerals by means of heavy liquids, to disregard the heavy minerals, and to consider only the light ones. A new method which was devised at the University of Illinois consists essentially of heavy-liquid separation in the centrifuge.

The procedure followed by the writers in this new method is as follows.

1. Grind to 80 mesh and place about 2 cc. of the powder in a 15-cc. graduated centrifuge tube.

2. Add about 10 cc. Thoulet's solution with a density of 2.75. Mix thoroughly with a glass rod and shake.

3. Centrifuge from 3 to 5 minutes at about 700 revolutions per minute.[1]

4. Pour off light (floating) fraction to a second tube.

If light material is not completely poured off, or if the medium and heavy material predominates greatly, repeat this step.

LIGHT

5. Recentrifuge in order to remove any heavy material that may be present and decant light portion into another tube.

6. Add sufficient water to decrease density until all material sinks.

7. Centrifuge and pour off the liquid, which can be used again after evaporation of the water.

8. Measure the volume of the light fraction.

9. Add *HCl* slowly to the measured light fraction until effervescence ceases entirely.

10. Centrifuge the insoluble residue for about 3 minutes and measure the volume of the sand and shale fractions directly.

11. Calculate the volume of the calcite by difference.

MEDIUM

12. Add all of the medium fractions together and centrifuge in Thoulet's solution with a density of 3.05.

13. Pour off the solution and that fraction which floats (the medium), observing the same precautions to insure complete separation as in the separation of the light fraction from the sample. The residue is the heavy fraction.

14. Add water and shake; centrifuge and decant liquid for future use.

15. Measure volume of the medium fraction.

16. Add concentrated *HCl* with a little HNO_3. Heat on water bath until effervescence ceases.

[1]A centrifugal milk tester can be fitted up so as to handle twenty-four samples simultaneously at about the same initial cost as that of the small hand centrifuges, whose capacity is four samples.

17. Centrifuge residue and calculate the volume of dolomite by difference.

HEAVY (from No. 13)

18. Add water to dissolve any iodides that have crystallized out.
19. Measure volume of heavy fraction.
20. Repeat procedure as in 16.
21. Calculate magnesite by difference.

Notes: If the light fraction predominates greatly, the initial separation (Nos. 1 to 3) may be made in a separatory funnel, the medium and heavy fractions drawn off from the bottom, and the operation continued as outlined. Where the heavy fraction is very small, or where the presence of magnesite is not suspected, Nos. 12, 13, 18, 19, 20, and 21, may be omitted.

Thoulet's solution is prepared by treating five parts (by weight) of mercuric iodide and four parts of potassium iodide in a casserole with a little water until a crystalline crust begins to form. The solution thus made has a density of about 3.15 and is diluted to the required densities with water. (Hydrometers having a range from 2.5 to 3.5 are necessary for this work.) The solution will keep indefinitely without decomposition provided a little mercury is added to it.

This solution is preferred for this work, even though it is very poisonous and if allowed to touch the skin inflicts rather unpleasant burns. Moreover, the mercury in the solution forms an amalgam with aluminum; therefore, the ordinary aluminum shields for centrifuge tubes can not be used effectively with the solution. Rubber gloves protect the hands, and the difficulty connected with the use of aluminum shields may be obviated by the use of brass shields. If brass shields are placed in Thoulet's solution, they become coated very rapidly with a film of metallic mercury, but no decomposition was observed nor was there any apparent weakening of the tube. The loss of mercury is, of course, important, but if a few drops of mercury are kept in the bottle containing the solution there is no apparent decrease in density.

These disadvantages pertaining to the use of Thoulet's solution are more than counterbalanced by its low cost, its adaptability to relatively high room temperatures, and its miscibility with water in all proportions.

Bromoform was tried with the idea of obtaining a more suitable liquid for the separation of the light and medium fractions, especially since the separation of the medium and heavy fractions is rarely necessary. It also is inexpensive and is, of course, noncorrosive. Considerable difficulty was found in keeping the density of the solution constant even if the tubes were corked while in use, as the benzine or alcohol necessary to dilute bromoform evaporates readily at room temperature. Moreover, since bromoform is not miscible with water, tubes must be

perfectly dry before use, a precaution that is unnecessary in the case of Thoulet's solution. The greatest difficulty in the use of bromoform was encountered when the solution was poured off and acid was added to dissolve the carbonates. The small amount of bromoform adhering to the rock particles retarded the solvent action of the acid and prevented an accurate reading of the volume of the insoluble residue.

The following table shows the efficiency of the method described as compared with the results of examining large fragments stained with Lemberg's solution and checked against calculations based on quantitative analyses of the same material as that used in the test.

It will be noticed that in every case the "insoluble" is greater in the results of the centrifuge method than in the results of the analysis. This is probably due to the fact that finer grinding than to 80 mesh and repeated evaporation to dryness during analysis result in the complete separation of insoluble from soluble material. Finer grinding would make the centrifuge method very difficult, owing to the difficulty of sinking fine particles in water. The error is not, however, any greater than the error made in assuming that a small amount of powder obtained from cuttings is an accurate sample of the formation to be tested.

The swelling of the shale fraction as noted by Trager[1] seems to be much more common than his statement implies. This difficulty, although not of great importance in pure or nearly pure carbonate rocks, may cause the introduction of very serious errors in work with argillaceous material. The main effect of swelling shales in the examination of limestones is to increase the insoluble parts and thus to increase considerably the error introduced by the calculation of volumes rather than weights. These errors which are inherent in the method are not of great importance, however, and do not affect the calcite-dolomite ratio, which is of great importance in correlating limestones.

If anyhydrite is present it will be partly dissolved when the medium fraction is treated with acid. In such a case it is necessary to precipitate the sulphate and calculate the amount of anyhydrite so dissolved in order to prevent error in the determination of the dolomite present.

The need for better methods in the study of subsurface relationships, the correlation of underground beds, and the recognition of buried unconformities is evident, particularly in the oil industry. Our knowledge of subsurface beds and their physical and chemical relationships must depend largely on physical and chemical analyses of drill cuttings

[1] *Op. cit.*, p. 174.

COMPARATIVE ANALYSES OF SIX SAMPLE LIMESTONES

No.	*Location*	*Thoulet's Solution Separatory Method*		*Calculations from Analyses*		*Lemberg's Staining Method*
1	Niagaran from the National Lime and Stone Company's quarry at Findlay, Ohio	Insoluble Calcite Dolomite	9.0 9.0 82.0	Insoluble plus Fe_2O_3 Calcite Dolomite	6.4 10.7 83.0 100.1	Very fine grain. No stain (i. e. calcite) observed. Unsatisfactory
2	Niagaran from the Monon Stone Company's quarry at Monon, Indiana	Insoluble Calcite Dolomite	4.0 6.0 90.0	Insoluble plus Fe_2O_3 Calcite Dolomite	2.0 6.7 91.5 100.2	A few large grains calcite, also cavity linings. Not more than 5 per cent. Satisfactory
3	Silurian from a quarry southwest of Muncie, Indiana	Insoluble Calcite Dolomite	17.0 7.0 76.0	Insoluble plus Fe_2O_3* Calcite Dolomite	2.2 9.7 87.9 99.8	Calcite lines cavities. Very irregular, not more than 5 per cent. Fairly satisfactory
4	Coral from the St. Mary Cement Company's quarry at St. Marys, Ontario, just above No. 5	Insoluble Calcite Dolomite	8.0 6.0 86.0	Insoluble plus Fe_2O_3 Calcite Dolomite	3.4 5.7 90.4 99.5	No stain observable. Cherty. Unsatisfactory
5	Onondaga from the same quarry as No. 4. Twenty feet above bottom of quarry	Insoluble Calcite Dolomite	3.0 94.0 3.0	Insoluble plus Fe_2O_3 Calcite Dolomite	1.1 98.2 .7 100.0	A few chert grains. No dolomite. Satisfactory
6	Onondaga from Mitchellsburg, Kentucky. Four feet below the Chattanooga shale	Insoluble Calcite Dolomite	16.0 20.0 64.0	Insoluble plus Fe_2O_3 Calcite Dolomite	11.1 23.0 65.7 99.8	No stain observable. Unsatisfactory

*Cherty variety in which four determinations of dolomite gave the following percentages: 76½, 76½, 75½, 76. There is clearly some physical property of this rock which renders dolomite insoluble by ordinary treatment with acid. Finer grinding might solve the difficulty, but the fine powder could not be easily separated.

and cores. The accurate determination of the mineral composition of limestones and dolomites is very important. The ratio of calcite to dolomite is especially significant and the relative amounts of sand, shale, and heavy minerals are also valuable.

The relative amounts of calcite and dolomite in a sediment may be used in the recognition of an unconformity, as present-day observations of our land surface in areas immediately underlain by calcareous sediments indicate that there must be an increased post-emergent porosity in limestone immediately below an unconformity, owing to differential solution at the time when the rock lay at the former land surface. This porosity formed during the erosion interval is attended by a leaching of the calcite with a retention of the dolomite. Therefore, in general, there tends to be a decrease in the calcite-dolomite ratio in that part of the limestone which lay above the water table and below the unconformity. The porosity can not be measured directly from the drill cuttings, but an accurate determination of the relative amounts of dolomite and calcite may throw much light on the geologic history and nature of the rock.

A CLASSIFICATION OF LIMESTONE RESERVOIRS[1]

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ABSTRACT

This paper contains a classification of limestone reservoirs based on the origin of the openings in the rock. It is shown that the most important type of reservoir is one in which porosity has been developed by erosion which took place before the time of deposition of the beds now overlying the reservoir. The other class of reservoir of major importance includes fractured limestones. The distribution of the different types of reservoirs in the United States is discussed briefly.

Since the bulk of the early oil production came from sand or sandstone reservoirs, the use of the term "oil sand" has become almost universal in America whether the actual reservoir rock be of sandstone, limestone, salt dome cap rock, or serpentine. The essential differences between types of reservoirs are so great as to introduce considerable confusion if the term "sand" is loosely used.

In comparing sandstones and limestones the observer is struck by the comparative uniformity in texture and size of openings in the former rock and the lack of such uniformity in the latter. Wells drilled into reservoirs of the former type behave with comparative regularity, and the relations between oil and water in sands have been definitely determined. The behavior of wells in limestone, on the other hand, is notoriously irregular, as are water conditions in limestone pools. Sandstone reservoirs are easily classified structurally if the lenticularity of all oil sands be recognized, whereas some limestone reservoirs seem to be quite independent of "structure."

This paper is the result of a preliminary attempt to classify limestone reservoirs. The subject has not been studied exhaustively and for

[1]Read before the Association at the San Francisco meeting, March 21, 1928. Manuscript received by the editor, October 12, 1928. This paper contains preliminary results obtained in an investigation on limestones and dolomites as reservoir rocks listed as Project No. 23 of American Petroleum Institute Research. Financial assistance in this work has been received from a research fund of the American Petroleum Institute donated by The Universal Oil Products Company. This fund is being administered by the Institute with the coöperation of the Central Petroleum Committee of the National Research Council.

[2]American Petroleum Institute Research Fellow, University of Illinois. Introduced by K. C. Heald.

this reason the proposed classification is but tentative. Modifications will probably be made from time to time as work progresses on the problem of limestones as reservoir rocks. The writer and his associates are now engaged in a detailed study of some of the more important areas in which oil is found in limestone, and it is hoped that this article may arouse discussion and bring suggestions that will correct errors and advance the investigation of this difficult subject.

IMPORTANCE OF LIMESTONE FIELDS

The importance of limestone fields is continually increasing, and it is believed that as much oil will be won from limestone as from sandstone within a few ye .s. In fact to-day two limestone fields have a daily potential production of approximately 5,000,000 barrels. This, of course, could not be maintained for any considerable length of time. Besides the newly discovered West Texas district, many of the older districts obtain much of their production from limestone. These include fields in Ohio, Indiana, Illinois, Kentucky, Michigan, and Tennessee, east of Mississippi River. In the Mid-Continent fields important amounts of oil come from Paleozoic limestones in Oklahoma and Kansas, as well as from west-central Texas and the Texas Panhandle. In northwestern Louisiana and in south and east Texas, limestones produce oil, and in the Rocky Mountain fields the Embar and Madison limestones are noteworthy producers. In foreign fields the Canadian, Mexican, and Persian production is practically all from limestone.

In 1917, A. W. Lauer[1] discussed the origin of openings in sedimentary rocks. His classification of openings in limestones and dolomites stressed the importance of induced openings rather than original openings. The discussion of this paper was directed toward reservoirs other than limestones, and the importance of induced openings was at that time believed to be slight.

NATURE OF LIMESTONE

In their work on limestones as reservoir rocks, the writer and his associates have considered as limestones those rocks which were laid down beneath bodies of standing water which originally consisted of relatively pure calcium and magnesium carbonate and which are not metamorphosed. This restriction of the use of the term removes from consideration calcareous sandstones and shales, travertine, calcareous

[1] A. W. Lauer, "Petrology of Reservoir Rocks," *Econ. Geol.*, Vol. 12 (1917), pp. 435-72.

tufa, salt dome cap rock, and, of course, marble. Dolomitic limestones are included regardless of their magnesium content, since there is no apparent division between dolomites and limestones.

Porous limestones may be classified according to the origin of their porosity as follows.

1. Limestones with primary porosity
   a. Chalk
   b. Oölitic limestone
   c. Primary crystalline dolomite and limestone
   d. Coral reefs
2. Limestones with secondary porosity
   a. Limestone associated with former erosion surfaces
   b. Limestone with porosity developed as a result of mineralogical changes
3. Fractured limestones
   a. Strongly jointed limestone
   b. Limestone fractured as a result of crustal movement
   c. Limestone fractured as a result of mineralogical changes

Limestones with primary porosity.—Limestones of this class may form reservoirs where associated with source rocks. Most limestones, however, have become compacted and cemented so that commercial reservoirs of this class are rare. In the United States they include some horizons in the Austin and Annona chalk.

W. A. J. M. van Waterschoot van der Gracht[1] reports

> in the Panhandle of Texas, for instance, and elsewhere. . . . I have found dolomites which consist of a more or less loosely packed aggregate of small dolomite crystals which apparently formed in the water and sank to the bottom. Rocks of this kind are physically like a sharp sandstone, only the grains do not consist of quartz crystals but of dolomite.

Limestones with secondary porosity.—This class of reservoir is by far the most important. The first group, namely, those in which porosity has been developed below former erosion surfaces, probably involves fully 95 per cent of the known limestone reservoirs, and these reservoirs probably have contained 95 per cent of the total production of oil from limestone. It is true that this statement is made after a merely superficial study of limestone reservoirs, but the opinion of the writer is supported by many references to oil fields in which limestone reservoirs are known to be associated with unconformities, as well as by the results of his own work on the problem.

[1]Personal communication.

Murray[1] shows that almost every limestone oil field in Ohio, Indiana, Michigan, Kentucky, Ontario, and Illinois obtains its production from a reservoir which lies within 100 feet of an unconformity. In Oklahoma, with the exception of production from the "Wilcox" sand, the bulk of the production from pre-Pennsylvanian rocks is derived from limestones all of which underlie unconformities,[2] with the possible exception of the Viola limestone. This limestone is generally considered to underlie the Sylvan shale conformably,[3] although in Arkansas a thin bed of conglomerate lies between beds correlated with the Sylvan shale and the Viola limestone.[4] In places, the Viola contains oil, even where overlain by the Sylvan shale, so that some consideration must be given this formation. Even if later work does not establish the presence of an unconformity at the top of the Viola, the basal member of the Hunton limestone is reported to lie unconformably upon the Sylvan shale.[5] In places where the Sylvan shales are not more than 75 feet thick, circulation could easily be set up within the more permeable limestones, and this circulation would cause the local development of some porosity. Thus, theoretically, the Viola should be a much poorer reservoir than the other pre-Pennsylvanian limestones of the state. This is borne out by the results of drilling.

In the Pennsylvanian formations of the Mid-Continent fields, production comes almost entirely from sand. A small amount of oil and gas is obtained from the "Big lime" and Fort Scott (Oswego) limestones. Much of the production from this group came at a time when limestones were not considered to be reservoir rocks and the reservoir was called a "sand." It is not clear, therefore, whether the production came altogether from sandy members, such as the Peru sand, or not. Whatever the fact, Greene[6] reports that the top of this formation is irregular in Pawnee County. Coal is reported in the Nowata shales overlying the Oolagah

[1]A. N. Murray, "Limestone Reservoirs of the Northeastern United States and Ontario, Canada. I. The Relations of the Producing Horizons to Unconformities." Paper submitted to the American Petroleum Institute.

[2]Luther H. White, "Subsurface Distribution and Correlation of the Pre-Chattanooga ('Wilcox' sand) Series of Northeastern Oklahoma," *Oklahoma Geol. Survey Bull. 40-B*, (1926).

[3]Luther H. White, *op. cit.*, p. 18.

[4]*Ibid.*

[5]*Bull. 2, Bureau of Geology*, Norman. Quoted by R. A. Conkling, *Oklahoma Geol. Survey Bull. 40-S*, (1927), p. 11.

[6]Frank C. Greene, "Geology of Pawnee County," *Oklahoma Geol. Survey Bull. 40-C*, (1928), p. 10.

("Big lime") limestone,[1] and coal is also found in the Bandera shale member in Kansas. This member disappears near Talala, Oklahoma, where the Pawnee limestone and Altamont limestone, which underlie and overlie it, continue toward the south as the Oolagah limestone. The presence of coal and the pinching-out of the shale indicate overlaps in this area.

In west-central Texas, there is much production from limestone, as well as some from sandstone. Most of this limestone production comes from the Bend series,—particularly from limestone members of the Smithwick shale and from the upper part of the Marble Falls limestone. A little oil has been found in the Ellenburger limestone. Although there is evidence of unconformities above the Smithwick and Ellenburger, there seems to be none above the Marble Falls limestone,[2] although one is placed there by Matteson.[3] The evidence seems to indicate that, although some of the reservoirs in this district are of this class, most belong to the group of fractured limestones.

In the Panhandle field of Texas, production is in part from limestone and in part from granite wash or arkose formed by subaerial disintegration of the granite ridge which traverses the area. Although Lilley[4] states that the oil has accumulated along unconformities, it is not clear that he refers to the oil in limestone, and the present writer could find no reference to the presence of an unconformity above the limestone-producing horizon, although one is suspected. In part, the Panhandle limestone may be classified in group 1*c*.

It is probably best to leave the classification of the Panhandle reservoir until later, as well as that of the producing horizons in the Westbrook field, Mitchell County, Texas. In the Westbrook field oil is found near the upper and lower contacts of the Clear Fork, and it is possible that the lower horizon is below the Clear Fork-Wichita contact. If this be true, the presence of unconformities may almost be taken for granted. The causes advanced for the porosity of this reservoir, namely, dolomitization, removal of anhydrite by solution, and incipient fracturing,[5] are not

[1]C. W. Shannon and others, "Coal in Oklahoma," *Oklahoma Geol. Survey Bull. 4* (1926), p. 47.

[2]R. C. Moore and F. B. Plummer, "Pennsylvanian Stratigraphy of Texas," *Jour. Geol.*, Vol. 30 (1922), pp. 18-42.

[3]W. C. Matteson, *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 3 (1919), pp. 143-211.

[4]R. A. Lilley, *The Geology of Petroleum and Natural Gas*, (New York, 1928), p. 135.

[5]E. C. Edwards and L. W. Orynski, "Westbrook Field, Mitchell County, Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 11 (1927), pp. 467-76.

sufficient to give rise to much porosity unless the anhydrite was removed by near-surface unsaturated solutions, and this would necessitate the former existence of a period of erosion when the upper part of the reservoir was exposed.

In the other fields of West Texas, the evidence now available to the writer indicates that porosity is associated with an unconformity, but it is recognized that when the full story is told it probably will not be a simple one. Sidney Powers[1] has discussed these relations. Conditions have also been summarized by C. D. Vertrees,[2] who says:

> In the Yates field on the flank of the structure is a considerable sand between the base of the anhydrite and the top of the "Big lime" or dolomite series, and this sand section is absent in many areas on top of the structure. On top of the structure, as on the flanks, the "Big lime" is very porous, in some places honey-combed, and we have noticed a conglomeratic appearance. The production is obtained from this honey-combed dolomite on the top of the structure, and the upper sand has proved very productive well down on the eastern flank. I think there is little doubt that at least the crest of the Yates structure was exposed to atmospheric weathering before the deposition of the overlying anhydrite beds.
>
> In the McElroy field there have been several fragments blown from wells when shot, which have much the appearance of weather-worn fragments, with even a slight amount of case-hardening on the outer surface. In the upper part of the "Big lime" series in this field there is found a considerable amount of anhydrite in the form of inclusions and much of the porosity in this field may be caused by the changing of this anhydrite into gypsum by surface waters as suggested by van der Gracht.
>
> In the Winkler County field several cores have been taken from wells showing a very irregular and wavy contact between the base of the anhydrite and the top of the dolomite series which would suggest an unconformity here. Also there have been fragments from the main producing horizon blown from wells in this field which look very much as though they had been weathered. One geologist has told me that a fragment was blown from the Independent No. 1, after it was shot, which was very round and was covered with a thin veneer of iron oxide. As this well was shot in the producing horizon, which is 300 feet below the contact of the dolomite series and the base of the anhydrite, the fragment was probably blown from that depth, indicating the possibility of two unconformities near the top of the "Big lime" in the Winkler field.

South and east of these fields, there is only one area of major importance producing from limestone below an unconformity. This is the Luling field, where conditions are described by E. H. Sellards[3] as follows:

[1]"Buried Ridges in West Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 11 (1927), pp. 1109-15.

[2]Personal communication.

[3]Personal communication.

With regard to the relation of the Edwards limestone and that which lies above: there is a very abrupt break which expresses itself in both lithology and fauna. The Georgetown in the producing field, and generally in this part of the state, differs in many respects from the Edwards. It is non-dolomitic, non-water bearing, relatively non-porous, somewhat shaly. The immediately underlying Edwards is dolomitic, highly porous and cavernous. In the microfauna there is an abrupt change.... The break here is such as might readily be a time and erosion break. These conditions do not hold farther southwest but they do hold in the region of the Luling field and generally in this part of the state.

In the Rocky Mountain fields, production is obtained from the Madison and Phosphoria[1] (Embar) limestones, both of which underlie unconformities.

In some places, where limestone is overlain unconformably by a later series, the basal formation of the latter is a limestone conglomerate and is composed chiefly of re-worked material removed from the underlying limestone by erosion. In such places, production may come not only from the weathered limestone itself, but also from the conglomerate which overlies it. This type of production is encountered in the Kevin-Sunburst field of Montana, where the oil is found in the base of the Ellis formation and in the Madison limestone. In the upper horizon of the Pine Island field in northern Louisiana, oil is found at the base of the Tokio formation and in the underlying limestone.[2]

Those limestones which are made porous by mineralogical changes within the rock include two sub-classes of which the first is not, in the strict sense, a limestone at all. This is the calcareous salt dome cap rock in which the calcite was introduced as a secondary mineral.[3]

The second sub-class is included more or less as a matter of form, as the writer is convinced of its unimportance but has not yet obtained sufficient evidence to warrant its exclusion from a classification of limestone reservoirs. This form of porosity is that which is believed to be developed as a result of the replacement of calcite by dolomite.

Any other mineralogical change by reason of which a mineral of low specific volume replaces one of higher specific volume may result in the development of porosity. Some limestone reservoirs may have formed in this way, but none is known at present.

[1]Willis T. Lee, *U. S. Geol. Survey Prof. Paper 149*, (1927,) p. 9.

[2]A. F. Crider, personal communication.

[3]M. I. Goldman, "Petrography of Salt Dome Cap Rock," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 9 (1925), pp. 42-78.

Fractured limestones.—With the exception of the third class, it is difficult to distinguish between the several classes of fractures in limestone. In fact, the features that distinguish a jointed limestone from a fractured limestone are regional rather than local. Some wells in the northeastern fields—notably near Terre Haute, Indiana, and in Tennessee—obtain their production from joints, and in the Luling and Pine Island fields some of the openings are undoubtedly caused by fracturing due to crustal movement.

Fractures, either single or in zones, are thought by some to control the distribution of oil in the Panuco field of Mexico and also to have been very important in the limestone production as opposed to the sandstone production of the Eastland and Stephens County fields of Texas. It is also recognized that joints and fissures may be very important in connection with unconformities, since waters circulating along them might develop linear areas of high porosity. Information at hand will not justify an attempt to discuss elaborately the rôle and importance of fissures in limestone fields.

Some of the porosity in the West Texas and Panhandle fields may be caused by fracturing as the result of hydration of anhydrite associated with the limestone. Swelling of the sulphate causes rupture of the rock.

SUMMARY AND CONCLUSIONS

Limestone reservoirs may be classified according to the manner in which porosity has been developed within them. Of the different classes the most important is the group of limestone reservoirs which have undergone subaerial erosion. The unconformity which represents this period of erosion need not be angular, nor is it necessarily easily discerned. In fact, any period of erosion which is of sufficiently long duration to give rise to a relief of more than a few feet seems to be sufficiently long to form an oil reservoir in limestone. Such reservoirs need not be associated with folding or faulting, nor need they all underlie hills sufficiently high to be reflected in surface structures.

The thickness of the "pay," as well as its depth below the upper contact of the limestone formation, is dependent on the water table during the period when the rock was being eroded, and the depth of the water table is controlled by the relief and the degree of aridity prevailing in the region. Thus in some fields the "pay" may be within a few feet of the erosion surface, whereas in others the upper 500 or 600 feet of a thick limestone series may have been rendered porous by downward circulating water. It is extremely unlikely that much solution is carried on below

the water table, because of the small amount of calcium carbonate which can be dissolved in water in the absence of carbon dioxide.

This indicates that any area where, at a reasonable depth, a limestone is overlain unconformably by source rocks of petroleum may be a favorable area for prospecting, regardless of structural conditions. Former hills, ridges, escarpments, and valley walls may form collecting reservoirs for oil. Thus paleo-topography, or the study of former land surfaces, may yield valuable results from the standpoint of petroleum.

In conclusion, the writer wishes to acknowledge with gratitude the assistance given by many geologists during the past year. To give each credit individually would be impossible, for scores have helped. It is hoped that these experienced geologists will continue to take an active interest in the work connected with this project, for, without their support, further progress is impossible.

GEOLOGICAL NOTES

NOTES ON THE PRINCIPLE AND THEORY OF ISOSTASY

Isostasy was considered, by the scientist who named it, to be an ideal condition of equilibrium, and therefore of equal pressures and of rest. It was defined by Dutton[1] as the "equilibrium of figure, to which gravitation tends to reduce a planetary body." Applied to the earth, isostasy has probably never been completely attained.

The operative principle of isostasy is clear from Dutton's definition of the basic word. It is the tendency toward equilibrium in accordance with the law of gravitation. The principle is always present.

The theory of isostasy, when separated from the principle, has to do with the apprehension, analysis, or explanation of such features as a particular amount of adjustment, approach toward equilibrium, or manner in which these features are brought about.

The theory has many variations as regards the earth. Most of these postulate a comparatively rigid crust floating on heavier viscous material. One variant assumes equal density but unequal vertical thickness of crustal blocks; another, that both density and thickness of the blocks are unequal; and so on. There is the variant which assumes that appreciable adjustment is expressed only by fairly large blocks of a rather strong crust, and the alternative variant which holds that it is noticeable in fairly small blocks of a weaker crust. There is the hypothesis that such adjustment closely parallels events disturbing a comparative equilibrium; again, that it lags appreciably behind disturbance and that parts of a crust being deformed seldom or never closely approach equilibrium.

There has been considerable confusion as regards a proper segregation of the principle of isostasy from the theory which has been built around it. In many publications on isostasy the geologist finds undisputed tendency intricately mixed with interpretations which he feels are at least doubtful, the whole being presented in such a way that to reject the theory he must seemingly also reject the principle. One of the most valuable and widely read works on isostasy, that by Bowie,[2] may be selected to illustrate this feature.

[1] C. E. Dutton, "On Some of the Greater Problems of Physical Geology," *Phil. Soc. of Washington, Bull. 11* (1899). Original definition.

[2] William Bowie, *Isostasy*, Dutton and Co., New York (1927).

Bowie presents, from his beginning, a hypothesis or variant of theory, the motif of which is sounded, and the essence of which is contained, in the first sentence of his book (p. 1). This variant is based primarily upon detailed and careful geodetic observations made by Bowie and others. However, (1) in making these observations certain basic values or conditions were assumed, (2) when defending his personal interpretation against unfavorable geologic evidence he sometimes relies unduly upon speculation opposed to the weight of this evidence, and (3) when interpreting data furnished by geodetic observations he commonly considers only one or two of a number of possible explanations. Such considerations forever separate theory from principle.

Yet he states (p. 53) that certain geodetic data "justify one in the conviction that the *theory of isostasy* has been changed to *principle of isostasy*." (The italics are his.) The tenor of his treatise shows that, when referring to principle, Bowie did not mean the tendency so carefully segregated by Dutton. It is clear (p. 1) that he had in mind a particular interpretation which involves a departure from Dutton's classic definition of isostasy.

The danger of assuming that theory which is open to attack is the same as principle, may be illustrated by showing that the points which have been made and listed are valid.

1. The use of assumed basic values (no matter how useful or praiseworthy) in the foundation of a theory prohibits its identity with principle. This feature is too obvious to require more than an admission of the use of such values.

2. When replying to the conclusion of Barrell[1] that a measure of crustal rigidity capable of sustaining to a large degree the downward strains due to the piling up and overthrusting of mountains built by tangential forces is indicated by a delta such as that of the Niger, which approximates 29,000 cubic miles of added mass when reduced to land equivalent, a maximum depth of 10,000 feet, and probably represents 6,000 vertical feet of additional load, Bowie (p. 86) says:

> We can explain the presence of this 6,000 feet of added material on the principle of isostasv if we assume that much more material has been deposited at the mouth of the Niger than the 10,000 feet. We have abundant evidence that tens of thousands of feet of sediments have been deposited in some localities, and why might there not be more than the 10,000 feet in the Niger delta?

The speculation expressed in this quotation cannot be accepted as disproving the evidence against local adjustment afforded by Barrell's calculations.

[1]Joseph Barrell, "The Strength of the Earth's Crust," *Jour. Geol.*, Vol. 22 (1914).

On page 212, Bowie makes the following statement:

> Then there are the ocean deeps or troughs close to and paralleling coasts of continents, or the axes of chains of islands. These could not have been caused by compressive horizontal forces; nor could they have been due to tensional forces.

With reference to the foregoing, it may be remarked that Taylor[1] has presented considerable evidence showing the possibility of compressive horizontal movement having caused such phenomena.

3. California evidence cited by Bowie is subject to more interpretations than he infers. When speaking immediately of topography and depth, but in general support of his theory postulating a high degree of isostatic compensation and its localization, he mentions (p. 78) that the maximum negative effect on gravity value recorded in the United States, −0.178 dyne, occurs at Compton, California. Farther on he compares the anomaly at this point, −0.050 dyne, with an anomaly of −0.022 dyne at Long Beach, 8 miles away.

Bowie does not, in this connection, adequately consider the feature that coastal California suffered, during the Cenozoic era, probably the largest amount of differential horizontal movement and tangential shortening of any portion of the United States. (Approximately 24 miles of horizontal movement is indicated to have taken place along the San Andreas rift fault alone in Cenozoic time, a figure which dwarfs all vertical movement of which we have record.) Nor does he mention the fact that one of the most nearly perfect known examples of differential horizontal movement occurs along the Newport-Beverly sheer zone[2] located half way between the two gravity stations which he cites. There are reasons to believe that compressive horizontal movement may have had something to do with the gravity values and anomalies mentioned by Bowie, and that such movement has a bearing on his theory. Leith[3] has discussed some possibilities along this line of thought.

In reviewing these points the writer does not wish to give the impression that he doubts the isostatic principle, its successful application, or the legitimacy of hypotheses when presented as such. He is developing a thesis which maintains that principle should be viewed separately from theory based upon interpretations that are open to attack. Regard-

[1] F. B. Taylor, "Greater Asia and Isostasy," *Amer. Jour. Sci.*, Vol. 12 (1926).

[2] J. E. Eaton, "A Contribution to the Geology of Los Angeles Basin, California," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10 (1926), p. 764.

[3] C. K. Leith, *Structural Geology*, Henry Holt and Co., New York (1923).

ing the particular illustration, the points mentioned would be minor if Bowie (p. 1) had not used the word *proved* when combining isostasy with geodetic data, thus closing the door. Now let us turn to some writers who have held other views.

Barrell[1] recognized two viewpoints regarding isostasy, the disputed and the undisputed. He used the term theory (general) in the sense wherein its meaning most nearly approaches that of principle, and viewed its field as being distinct from that of competing hypotheses.

Swanson[2] has also divided features pertaining to isostasy into two divisions. He uses the term *general* theory instead of principle, the use of the adjective denoting segregation from any particular hypothesis. He says:

> In order to keep clearly in mind what is known concerning the existent isostatic equilibrium it is useful to adopt Barrell's distinction between the general theory of isostasy and the various working hypotheses of isostasy.[3] Thus there will be avoided the error of dismissing the broad concept of isostasy because one cannot accept any of the definitions of isostatic balance.
>
> The general theory of isostasy holds that there is a tendency toward the attainment of the ideal isostatic condition defined by Dutton. The extent of this tendency is indicated by certain broad limits which are accepted by almost everyone.

The present writer suggests that much confusion can be obviated by using the unqualified term *principle* to designate the tendency toward isostatic equilibrium, and the unqualified term *theory* to represent both individually and collectively the various hypotheses seeking to explain such phenomena as may result from this tendency. Regardless of whether this suggestion is or is not favorably received, there is need for some agreed usage that will segregate a principle regarding which there is little dispute, from theories regarding which there may never be complete agreement.

J. E. Eaton

Los Angeles, California
October 8, 1928

CLAY CREEK DOME, WASHINGTON COUNTY, TEXAS

Oil and gas were recently discovered on a structure which has all the earmarks of a salt dome, 12 miles north of Brenham, in Washington

[1]Joseph Barrell, "The Status of the Theory of Isostasy," *Amer. Jour. Sci.*, Vol. 48 (1919), pp. 292 and 293.

[2]C. O. Swanson, "Isostasy and Mountain Building," *Jour. Geol.*, Vol. 36 (1928). p. 413.

[3]Joseph Barrell, *op. cit.*, p. 293.

County, Texas. This is known as the "Clay Creek dome." It belongs in the group of interior domes. Surface evidence of the structure was discovered by W. B. Ferguson, who, with L. W. Storm, both geologists with the Sun Oil Company, mapped the area in June, 1926.

On September 15, 1928, the Sun Oil Company's discovery well, Grote No. 1, blew in unexpectedly, producing gas estimated between 40,000,000 and 60,000,000 cubic feet per day, from a total depth of 978 feet. This sand was cased off, and on October 9, after screen had been set at 1,154 feet, the well began producing between 200 and 300 barrels of oil per day. This oil has a gravity of approximately 26° Bé. It comes from a sand in the upper Cook Mountain formation (Eocene).

The Grote No. 1 was the second hole drilled by the Sun Oil Company on its block, the first being a dry hole, Schirmer No. 1, 2,000 feet southeast of Grote No. 1, abandoned at a total depth of 4,271 feet.

FREDERIC H. LAHEE

DALLAS, TEXAS
October 22, 1928

PSEUDO-STRATIFICATION IN CORE RECOVERIES

A peculiar effect produced in coring operations with rotary core barrels, that may cause an entirely wrong interpretation of core dips, is very common in soft sedimentary strata, especially in clays, soft shales, and sandy shales.

The accompanying photograph (Fig. 1) illustrates this result in a striking example. It is a core recovery from an unbedded mottled clay formation. The mottled clay is light-colored, non-bedded clay or sandy clay with irregular splotches of red color. The regular dark bands in the picture are red and represent a re-worked formation and admixed drill mud, which had been forced in between regular partings caused by the breaking of the core of the true formation.

All the evidence proving that this seeming stratification is an effect produced during coring rather than an actually banded formation is difficult to present in a brief note, but an examination of many cores of various colors and lithologic types makes the conclusion certain. Cores of fossiliferous green shale have been noticed with re-worked bands of gray mud of the same color and texture as the material coating the core before it is cleaned off. The bands of re-worked material are regularly similar to the material coating the core when removed from the core barrel, but the laboratory worker may not see many uncleaned cores and therefore may not observe this fact.

All cores broken open along the surface separating these bands show a spiral slickenside effect in the re-worked band, indicating a twisting of the core at these lines of breakage. Ordinarily the surface of the parting is concave on this side and convex on the side of the true formation. The

FIG. 1.—Photograph of a core of an unbedded mottled clay formation. The dark bands represent a mixture of re-worked formation and drill mud.

effect may be so marked that the core consists only of several discoid "buttons" of the true formation separated by the bands of re-worked material, and many of the latter may be as thick as the bands of the true formation, or thicker.

The assumption that this is a true banding in sedimentary rocks will obviously be very misleading, as it almost invariably indicates a flat (horizontal) dip; and if the formation actually has a dip, it gives the effect of small-scale cross-bedding.

Another peculiar effect produced on soft clastic rocks in drilling, is commonly observed in bit samples. Bit samples from these same mottled clays or from any other sandy clay or soft shale commonly show a fine lamination. This lamination is a banding (textural and color) on a very small scale, commonly showing several bands per millimeter. Undeformed core samples from approximately the same depth do not show this type of fine lamination. This relation of finely laminated bit samples to non-laminated core samples is observed so commonly that it seems evident that the lamination is a result of drilling operations on the formation.

M. N. BRAMLETTE

YALE UNIVERSITY
NEW HAVEN, CONNECTICUT
October, 1928

REVIEWS AND NEW PUBLICATIONS

"Initial Dips Peripheral to Resurrected Hills." By JOSIAH BRIDGE and C. L. DAKE. *Missouri Bureau of Geology and Mines 55th Biennial Report.* Rolla, Missouri, 1928. Appendix 1, pp. 1-7.

The buried and resurrected hills of the St. Francois Mountains, southeast Missouri, have long adorned the geological map of the state, but have remained in obscurity. Two areas in which these porphyry and granite knobs are most plentiful, Ironton and Eminence, are readily accessible, and the authors, on application, will furnish detailed maps showing where the few exposed contacts between the granitic hills and the sub-adjacent sedimentary rocks can be observed. The reasons given why these knobs are almost confined to two areas are the deep dissection of the sedimentary rocks in them and the resistance to erosion of the porphyry which may have been removed from above the granite elsewhere in pre-Cambrian time.

When Cambrian seas invaded the region the topographic relief reached a maximum of about 2,000 feet. The knobs stood in their present topographic form as islands and reefs in the Cambrian sea just as the granite knobs of the Wichita Mountains stood as hills during Permian sedimentation. In both places the sedimentary rocks dip quaquaversally from the granitic rocks with dips as great as 30°, and in both places it is possible to walk up dip slopes a vertical distance of as much as 200 feet. In Missouri the sedimentary rocks are sandstone and dolomite; in Oklahoma, sandstone and arkose. Detritus from the knobs is found in the sedimentary rocks in both areas.

Bridge and Dake maintain that the dips peripheral to the knobs are due primarily to initial deposition on an inclined plane and secondarily to later solution which may have thinned some of the dolomites to 40 per cent of the original thickness. They point out that the knobs were largely submerged, as proved by successive overlaps on their flanks, and that the contemporaneous subaqueous relief was great, as indicated by the extension of older rocks up on their flanks. The dips are everywhere toward the axes of pre-Cambrian drainage lines—the present synclines. "Since no one of these lines shows more prominent dips than any other, there seems to be valid reason for believing that none of them has been measurably intensified by later deformation." Further substantiation of this contention is shown in the dips in the Cambrian and Ordovician rocks, which are very slight in the St. Francois Mountains except near and over these knobs.

The reviewer believes that the evidence that the entire angle of dips is wholly initial is inconclusive, and that part of it is undoubtedly due to solution and compaction. Dolomites overlie sandstones in the outcrops around the knobs. Yet, lead and zinc, deposited by circulating underground waters in underground channels at the base of the sedimentary section, are the quest of the mining companies who drill into the pre-Cambrian lowlands between and

on the flanks of the knobs. The reviewer conceives of regional compaction, due largely to free underground circulation of waters, as connected with that due to lithification. Such thinning—compression— of the sedimentary rocks would create dips toward the *main* axial lines of the pre-Cambrian valleys into and over which the sedimentary rocks should show *no initial* dips. The reviewer recognizes the lack of evidence of subsequent local folding in the area.

Reverting again to the analogy of the Wichita knobs, some of which have been found by shallow drilling on anticlines near those which have been resurrected by erosion, it has been generally conceded that the peripheral dips are caused in large part by settling, even though the stratigraphic section is largely sand with a little shale. The rocks are younger, less lithified, insoluble, and more easily compacted than those in Missouri. The sedimentary rocks between distant Wichita knobs dip as gently and homoclinally as do those in Missouri.

The Oklahoma geologists must accept initial dips as part of the geologic history, and the Missouri geologists must still convince them that underground waters have not carried away some of the foundation stones and allowed the valley fillings to slide a little deeper into the basins.

SIDNEY POWERS

TULSA, OKLAHOMA
November, 1928

"Sur l'un des problems tectoniques du R'Arb (Maroc)." By PIERRE TERMIER. *Bulletin Societé Geologique de France* (4), t. 28 (1928), No. 1-2. Pp. 3-17. In French.

The structure of the region is fairly simple. Some rather sharp and some rather broad, flat anticlines affect all formations but the Sahelian (upper Miocene). In the anticlinal zones, erosion has exposed lower Helvetian (lower Miocene) and in places uncovered domes of Nummulitic (Eocene). The local folding within the anticlines is somewhat complicated and in two directions at right angles. Triassic crops out where the base of the Helvetian, or of the Burdigalian (Miocene), is exposed, but in no place in the synclinal areas of thick Miocene. The Triassic areas are aligned parallel with the trend of the major folding. The Triassic has been regarded as the remnants of an overthrust nappe by Lutard and Daguin and as diapir intrusions by Brives, Mrazec, and Savornin. The author concludes that these Triassic outcrops are the remnants of dissolved salt domes.

The paper is without maps or sections. The descriptions seem to indicate diapir structure, but not to necessitate the assumption of much solution or to preclude the possibility that the salt cores characteristic of salt domes do not underlie the Triassic.

DONALD C. BARTON

HOUSTON, TEXAS
November, 1928

The Geology of Petroleum and Natural Gas. By ERNEST RAYMOND LILLEY. *D. Van Nostrand Co., Inc.*, New York, 1928. 524 pp., 173 figs., 61 tables. Price, $6.00.

Of first importance in judging the accomplishment of any book is knowledge of the classes of readers for whom it is intended. According to the author, this book has been written to supply individuals who are actively practicing the profession of petroleum geology, with a single volume in which they may find brief statements of principles of the science and examples illustrative of the application of those principles. He also hopes that the student who is preparing to enter this field of work will find in this book an adequate statement of the principles that he is studying. In the opinion of the reviewer the book is better adapted to fill the needs of the second group mentioned than the first. Perhaps teachers and students will maintain the contrary. In the opening pages the author states that he has been constrained to give preference to references available in libraries in the United States. Doubtless such a book can be written with less effort, but its value to the experienced American petroleum geologist would have been enhanced if a larger proportion of local data had been limited to footnotes, and materials from relatively inaccessible foreign sources had been used more generously. Members of the A. A. P. G. will be interested to know that more than fifty of the illustrations used are from the pages of the *Bulletin*. The book stresses structure almost to the exclusion of such highly important factors as source beds and paleogeography.

The early chapters are taken up with discussion of the chemical and physical properties of petroleum, its origin and its relation to other bituminous substances. Chapter III contains a classification of bituminous and related substances in which coals, even of anthracite grade, are included. In the reviewer's opinion, ordinary coals have no place in a classification of bitumens, and he also disagrees with the author's statement in the introductory chapter that " * * * normal coals and petroleum have so many chemical properties in common and are so closely related in geographical and geological distribution that there is ample evidence to warrant the belief that they are genetically related." The author joins the crowd in his conclusion that petroleum originated from organic sources. He considers kerogen an intermediate substance between organic débris and petroleum, and believes that dynamic pressures acting horizontally are chiefly responsible for the alteration products. Doubtless this is still the orthodox view, although the contention of Murray Stuart that oil is syngenetic appears to be gaining ground.

Chapter VI, which seems out of place, gives a brief survey of the stratigraphic column for the purpose of pointing out the relative importance, as oil producers, of the different geologic systems. A number of type sections are given from the world's principal oil provinces. In reading this chapter the impression is gained that the author's interest in this phase of his subject is far from keen.

Chapter VII resumes discussion of general principles and treats of the origin and nature of reservoir rocks. The causes of porosity are classified as primary and secondary. Just why the introduction of cementing matter should be listed as one of the causes for porosity is not clear. Although the porosity

of clastic rocks is discussed at some length, the importance of limestone reservoirs is under-emphasized. The important recovery of oil from Ordovician limestones of the Mid-Continent fields and the Permian limestones of West Texas is not mentioned in this connection.

Taking up commercial concentrations of oil, the author assumes that there has been migration (which is not universally admitted), states his belief in the gravitational theory of accumulation, and holds that the underlying pressure in all fields is hydrostatic. Producing sands, he believes, are separated from contiguous dry sands by capillary water or cementation.

Chapters IX to XI, inclusive, contain elementary discussion of what is meant by oil-field structures, their origin, and how they may be illustrated. The expression "sand map" (p. 228) is used unhappily instead of isopach map of a sand body. In practice isopach maps are made of any lithologic unit of variable thickness, but let us hope that "lime maps" and "shale maps," and in future "sand maps," may be kept out of geological literature.

The second half of the book is given to a classification of oil accumulations and descriptions of pools considered to be representative of each group. This is the distinctive feature of the book, as earlier works for the most part have been content to group oil fields geographically for purposes of description and discussion. In the reviewer's opinion the result here is none too successful, but the attempt is worth while, and an entirely satisfactory classification is perhaps impossible in the light of present knowledge.

In Group I are placed the pools due primarily to folding. The terminology is rather unfortunate, since nowhere are there accumulations in flat-lying beds, and in some degree folding, at least of a monoclinal type, has its effect on all pools. The dome and the anticline are the typical traps for this group. Accumulations on terraces are also included here, but the illustrations given are so inconsequential as to raise the question whether there is any important production anywhere due to the terrace type of structure. Many accumulations hitherto assigned to terrace structures are in reality controlled by varying porosity of the reservoir rocks and by the fact that, although a terrace only may be present in the surface beds, a closure exists at the producing horizon. Accumulations on monoclines due to sealed outcrops are listed in this group but properly belong elsewhere.

In Group II are gathered the pools that are dominated by faulting. With one exception the types given are either from the Balcones fault area of Texas or from California. The group seems to be a logical one, but it is a fact that although each structure illustrated is affected by a fault of striking proportions, it is rarely clear that an accumulation would not have taken place had deformation stopped short of the faulting stage.

In Group III are placed accumulations controlled by porosity variations. Burbank and Glenn pools in Oklahoma are outstanding examples of this group. It is striking that all illustrations are of lensing sands only. No example is cited of accumulations due to varying porosity in limestone. Production from fissures is also classed here, although with little or no justification.

The unimportant accumulations in serpentine and other igneous rocks are dignified by classification as Group IV.

The very striking and distinctive type of accumulations associated with salt cores are considered in Group V. The discussion is properly opened by

description of the better known structures of this kind in Germany and Roumania. The author accepts the view that plastic flow stimulated by isostatic pressures and movement in the basement rocks has caused the salt domes of the United States Gulf Coastal plains.

Group VI is designated as accumulations in complex structures. It is a catch-all that leads to questioning the whole scheme of classification. In it are cast such prominent and different pools as Amarillo, Salt Creek, Cushing, Tonkawa, Healdton, El Dorado (Kansas), and the Golden Lane of Mexico. It is not a happy grouping and all of the examples cited in it can either be assigned to previously mentioned groups or gathered in a group entitled "Accumulations Related to Unconformities." In fact, if the reviewer were attempting a genetic classification of oil accumulations, the last-mentioned title would head an outstanding group. Under such a title also belong the accumulations caused by sealed outcrops previously mentioned.

The book is closed with a chapter on exploration of new areas. The importance of surface occurrences of petroleum is overstressed. In fact it is stated that "up to the present the search for new areas that would be suitable for detailed study has been largely restricted to search for an examination of reported surface indications of petroleum." Reading that, the shade of Eötvös may rest more peacefully.

Throughout the text a number of new terms are suggested. In Chapter I it is proposed that pool, district, field, and province be used in the order named in referring to producing areas of increasing geographic significance. The reviewer believes the defining of these terms to be worth while, but holds the order, pool, field, district, and province would be more logical and in accord with partly established usage. In Chapter VI "container rock" is proposed for reservoir rock and "retainer rock" for the impervious covering. In Chapter XVII the term "covered structure" is proposed for deep folds that are but faintly reflected at the surface, and "buried structure" for folds with no indications of folding in surface beds.

As mentioned in the beginning, the reviewer believes this book will be useful to teachers and beginning students in petroleum geology. Certainly it is more up to date than its predecessors and it could not have quoted so copiously from excellent sources without possessing merit. He believes, however, that mature petroleum geologists who have been well trained in geologic theory, and who have kept in touch with publications such as those of the United States Geological Survey, Economic Geology, and the American Association of Petroleum Geologists, will find little in it that is new to them either in theory or in fact. Its usefulness for such will be for reference purposes only.

W. B. Wilson

Tulsa, Oklahoma
November, 1928

RECENT PUBLICATIONS

GENERAL

"A Compilation of All Published Matter Regarding Surveying of Deep Borings with Relation to General Subsurface Correlation and Practical Op-

eration," by H. B. Goodrich. Paper read before the Tulsa Geological Society, December 4, 1926, and published under title of "Crooked Hole Problem being Studied" in *Oil and Gas Journal*, November 15, 1928, pp. 38, 111, and 114. Mr. Goodrich also has a discussion on the "Importance of Crooked Hole Problem" on page 165.

"Results of Magnetic Observations in 1927." *U. S. Coast and Geodetic Survey Serial No. 423* (1928). Superintendent of Documents, Government Printing Office, Washington, D. C.

GEOPHYSICS

Geophysical News and Review of Geophysical Literature, compiled by John H. Wilson for the department of geophysics, Colorado School of Mines, Golden, Colorado. An annotated bibliography issued in mimeographed form. Vol. 1, No. 8 (September 15, 1928). Pp. 102a-122. Copies sent upon application.

MISSOURI

"Initial Dips Peripheral to Resurrected Hills," by Josiah Bridge and C. L. Dake. *Missouri Bureau of Geology and Mines 55th Biennial Report*, Rolla, Missouri, 1928. Appendix 1, pp. 1-7.

OKLAHOMA

"Engineering Report on Seminole Field, Oklahoma," by C. R. Swarts, C. R. Bopp, and W. S. Morris. *U. S. Bureau of Mines*, Washington, D. C., in coöperation with the *State of Oklahoma*, 1928.

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The Executive Committee has approved for publication the names of the following applicants for membership in the Association. This does not constitute an election, but places the names before the membership at large. In case any member has information bearing on the qualifications of these applicants, please send it promptly to J. P. D. Hull, Business Manager, Box 1852, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each applicant.)

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AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

ROSWELL H. JOHNSON, of the University of Pittsburgh, was again in Russia and Siberia the past summer, this time returning by way of China and Japan, getting through just a week before the cutting of the Chinese Eastern Railroad by Outer Mongolians, and reaching Peking by boat because of the cutting of the Peking-Mukden Railroad by the Manchurians.

NORBERT T. LINDTROP, chief geologist, Grosny Kabardinskaja No. 3, U. S. S. R., is the author of two papers in Russian: "Oil Conservation in Grosny and California," and "Wildcatting in the Northeastern Part of Caucasus." The latter appeared in *Neftjanoe Chosjaistvo No. 3*, pp. 416-24, and is illustrated by two maps and a profile.

MAX W. BALL, of Denver, Colorado, has resigned as president of the Argo Oil Company and has been elected president of the Araucana Corporation, recently organized for operation in Chile. Mr. Ball has opened offices for consulting practice in the First National Bank Building, Denver, and the Exchange National Bank Building, Tulsa.

ROY HOLLOMAN, lately associated with DEAN E. WINCHESTER in consulting work in the Rocky Mountain region, is in charge of geological exploration for the Araucana Corporation, whose South American office is to be in Punta Arenas, Chile.

RICHARD T. LYONS, who has been in charge of the land and geological departments of the Skelly Oil Company, Tulsa, Oklahoma, for the past year, has been elected a vice-president and a director of the company.

JERRY B. NEWBY has resigned as vice-president of the Petroleum Reclamation Company of Bradford, Pennsylvania, and will probably move to Oklahoma City.

LOUIS ROARK and W. A. BURRESS, petroleum geologists, have opened an office at 500-02 McCulloch Building, Okmulgee, Oklahoma, for the practice of general consulting work.

ESTHER S. JOHNSTON, editor of *The Geological Review*, has moved the editorial office from Denver, Colorado, to Los Angeles, California. The address is Box 1122, Station C. Mrs. Johnston is also employed in the geological department of The Texas Company.

KENNETH A. JOHNSTON, formerly connected with the Midwest Refining Company at Denver, Colorado, is now employed in the geological department of The Texas Company at Los Angeles, California.

JOSIAH BRIDGE, professor of paleontology and stratigraphy at the Missouri School of Mines, has been granted sabbatical leave for the college year of

1928-29. He is spending the year at Princeton University conducting research on the paleontology of the Cambrian and Lower Ordovician formations of the Ozark uplift.

F. B. PLUMMER, who has been with the Vacuum Oil Company at Fort Worth, Texas, is now attached to the staff of the Bureau of Economic Geology at Austin, Texas.

DEAN E. WINCHESTER, consulting geologist, announces the removal of his offices from 232 Steel Building to 307-08 C. A. Johnson Building, Denver, Colorado.

W. L. MILLER is vice-president and chief geologist of the newly organized Ramsey Petroleum Corporation, Petroleum Building, Oklahoma City, Oklahoma.

W. F. CHISHOLM, director of the minerals division of the Louisiana Department of Conservation, Shreveport, Louisiana, was re-elected president of the Petroleum Conservation Bureau. The bureau is composed of representatives from state and government conservation agencies.

C. E. JOHNSON is expected to return to his home in New York about January 1, after spending several months in Venezuela.

JOHN A. BOWNOCKER, chairman of the department of geology at the Ohio State University since 1916 and director of the Geological Survey of Ohio since 1906, died at his home in Columbus, Ohio, on October 20, at the age of 63 years.

WALTER A. BUCHER, of the University of Cincinnati, gave six lectures at Princeton University in November, on "The Origin of Earth Structure."

Registration at the A. A. P. G. booth at the Fifth International Petroleum Exposition at Tulsa, Oklahoma, October 20-29, 1928, showed an attendance of 350 geologists from 14 states. Representatives of 6 foreign countries also registered.

GEORGE F. BARNWELL, geologist for the Standard Oil Company in Java, is visiting in the United States. Mr. Barnwell's home is in Vancouver, Canada.

E. G. PATTLE, warden of the oil fields of Burma, has been visiting the fields of the United States. Mr. Pattle addressed the Tulsa Geological Society at luncheon, November 1.

E. U. VON BUELOW has resigned as vice-president and director of the North American Exploration Company, Inc., and after a short trip to Germany to study new geophysical methods and devices, has opened offices as consulting geologist and geophysicist at 509 Seventeenth Street, Denver, Colorado.

WILLIS STORM, geologist for Pettigrew and Meyer, Inc., is situated at 905 Exchange National Bank Building, Tulsa, Oklahoma.

CHARLES C. TOOMEY, geologist of Tulsa, Oklahoma, has been elected vice-president and general manager of the Midco Oil Company.

JEFFERSON A. STONE of the staff of the Oklahoma Geological Survey at Norman, Oklahoma, who sustained a fracture of the skull in an automobile collision last month, is recovering.

E. J. LEHNER, geologist for the Trinidad Leaseholds, Ltd., Trinidad, B. W. I., who visited the United States in October and November, was among the passengers rescued from the *Vestris* which sank off the Atlantic Coast last month.

The annual meeting of the American Association for the Advancement of Science will be held in New York City December 27, 1928, to January 2, 1929. The Hotel Lincoln is general headquarters. Section E, Geology and Geography, will have headquarters at the Astor and Bretton Hall. The following societies will hold meetings: Geological Society of America, Society of Economic Geologists, Paleontological Society of America, and Mineralogical Society of America.

ERNEST R. LILLEY is the author of an article on "Early Day Over-Production Problems" in the *Oil and Gas Journal* of November 15.

A. L. SELIG, head of the geological department of the Southern Crude Oil Purchasing Company, has moved his office from Shreveport, Louisiana, to Fort Worth, Texas.

CECIL D. ROBINSON, 418 Smith Avenue, El Dorado, Arkansas, is working in the Arkansas Valley for the Arkansas Natural Gas Corporation of Shreveport, Louisiana.

RALPH BREHM, geologist in charge of subsurface work in the Rocky Mountain region for The Texas Production Company, recently gave several lectures to the class in sedimentary petrography at the Colorado School of Mines, Golden, Colorado.

EUROPEAN GEOPHYSICAL NOTES

A department of applied geophysics has been instituted by the University of Breslau, Germany, and L. Mintrop, founder and managing director of *Seismos*, managing director of Exploration, and president of the North American Exploration, has been named head of the department and professor of geophysics. Dr. Mintrop will continue his connections with the commercial applications of geophysics.

The Prussian Geological Survey has a division for the Physical Investigation of the Earth's Crust. B. Kühn is director of the division. During the year 1927, torsion-balance surveys were made by Kühn in the area of the northwest extension of the Flechting structural ridge, north of the Weser, around the Hänigsen salt dome, and on two profiles across magnetic maxima in east Prussia. Rather detailed reconnaissance magnetic surveys with the vertical variometer were made by Dr. Reich in Schleswig-Holstein, in the Harz, in the area of the Baltic shield of the Province of Pomerania, and around the location of a contemplated government well in upper Silesia, and by Ing. Kohl on some of the salt domes of the Hannover district, in the Odenwald, on the magnetic iron ore deposits of Silesia, and the coal deposits of Mark Brandenburg. A seismic survey was made by Barsch, Reich, and Ebert on the gravitational-magnetic anomalies in east Priegnitz, and experimental work with the method was carried on at Rudersdorf near Berlin. Dr. Ebert continued his

experimental work with the electro-magnetic method on the Rammelsberg near Goslar.

During 1928, work has been under way or contemplated as follows. Application of the several geophysical methods is being made to various mining problems in connection with the ore deposits of the Harz. Kühn is continuing his torsion-balance survey of the northwestern continuation of the Flechting structural ridge, and Barsch is continuing his torsion-balance surveys of salt domes in the Hannover district and of the areas of magnetic disturbance in east Prussia. Magnetic surveys are being, or are to be, made by Kegel, Reich, and Kaemmerer, in investigation of the applicability of the magnetic method to the hematite and magnetite deposits, in the diabase-rich areas of Lahn and Dill in Hessen-Nassau; by Kohl, on a salt dome; and by Reich, in the area of the lower Elbe and in the area of the west edge of the Russian shield in eastern Pomerania. The investigations using the seismic method in east Priegnitz are being, or are to be, continued by Barsch, Reich, and Ebert. Ebert will also continue his testing of the electric method at Rammelsberg and in the upper Harz and will make trials of radiometric measurements.

It is interesting that in impoverished Germany, heavily burdened with taxes, the Prussian Geological Survey has undertaken a very considerable geophysical program whose purpose is by no means entirely "practical," while in the rich United States, neither any state geological survey nor the U. S. Geological Survey is doing or planning to do any geophysical work, and the only field geophysical work done under governmental or semi-governmental auspices is the very modest program of the U. S. Bureau of Mines and the Colorado School of Mines.

F. Schuh of the University of Rostock and of the Mecklenburg Geological Survey is making a detailed areal magnetometric survey of Mecklenburg with the Schmidt-Lloyd magnetometer, and is commencing a torsion-balance survey.

Not much commercial geophysical work is being done in Germany. Most German geophysicists are engaged in foreign work. A few torsion balances are being run in northern Germany. *Seismos* is doing a little work on iron ore deposits. More wigglestick work is being done, perhaps, than geophysical work.

A field mechanical seismograph designed by Prof. Schweydar, registering the horizontal component as well as the vertical component, is being manufactured for sale by Askania Werke. The Dutch Shell troops of the Roxana Petroleum Corporation are equipped with it.

The number of torsion balances constructed to date by Askania Werke is: large, 120; 40-cm. beam "Z" type, 54; 30-cm. beam "Z" type, 16. (Not many of this very small type have been sent to the United States).

In France the École Nationale du Petrole of Strasbourg has been conducting experiments with various geophysical methods. D. Pekar has been making a torsion-balance survey near Clermont-Ferrand.

The new baby Oertling designed by H. Shaw of the Science Museum, London, is a very neat little instrument. It has an overall height of less than 4 feet and an overall diameter of about 1 foot, is easily carried by one man, and is read visually. A station can be taken in 2 hours. The design of the working system is a new departure; the beam has three arms at 120°; two arms carry the lower weights, and the third, an upright arm, carries the upper

weight. Captain Shaw and E. Lancaster Jones have had good results with the instrument in an extensive field survey under trying conditions. Two of these torsion balances are being tried out in the experimental geophysical work by the Australian government.

DONALD C. BARTON

INDEX TO VOLUME 12

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SPACE FOR PROFESSIONAL CARDS IS RESERVED FOR ACTIVE MEMBERS OF THE ASSOCIATION. FOR RATES, APPLY TO THE BUSINESS MANAGER, BOX 1852, TULSA, OKLAHOMA

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CONTENTS OF VOLUME 12

PART 1

NUMBER 1

NUMBER 2

NUMBER 6

Errata

P. 80 Center heading: DIMENSIONS FOR MINIMUM VISIBILITY, not Maximum.

In first line following the equation: m = *Minimum*, not Maximum.

P. 82 Third center heading: DIMENSIONS FOR MINIMUM VISIBILITY, not Good.

In second line under this heading: *minimum* visibility, not good.

P. 530 In line 4, omit "*Sun Oil Company*."

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VOLUME 12

JANUARY—DECEMBER 1928

PART 2

PAGES 693-1204

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CONTENTS OF VOLUME 12

PART 2

NUMBER 7

NUMBER 8

NUMBER 9

NUMBER 10

NUMBER 11

NUMBER 12

ERRATA

Pp. 763-64	T. *17* S., R. *14* W., not T. 14 S., R. 11 W.
P. 766	In date line: Oklahoma *Geological* Survey, not Geographical.
P. 847	In line 5, last word: *overthrusts*, not underthrusts.
P. 848	In line 15: Planes *of* folding, not for.
P. 991	Under Stovall Drlg. Co. - Mitchell No. 1: 20-*17* N., not 16. Under Roxana Pet. Co. - Tensas Delta No. 2: 1 - *14* N., not 15.

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